Title of the Invention

TRANSMISSION DIVERSITY WITH TWO CROSS-POLARISED ANTENNAS ARRAYS

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Field of the Invention

The present invention relates to a method for selecting a
diversity mode to be applied by a transmitter having two
10 cross-polarized antenna arrays.

Background of the invention

In detail, the present invention relates to the field of
15 transmit antenna diversity. A rather comprehensive
introduction to the technical filed of diversity is for
example given by Juha Korhonen in „Introduction to 3G
mobile communications„, chapter 3.4., page 86 to 94,
Artech House mobile communications series, 2001. More
20 specifically, The concern of this invention resides in a
mode selection procedure by which a suitable transmit
diversity mode for each link in the cell defined by the
coverage area of the subject transmitter can be selected.

25 It is to be noted that while reference is made to an
antenna array, an array comprising a single antenna only
may still be regarded as an antenna array. Likewise, an
antenna and/or antenna element of the array produces a
beam of electromagnetic radiation in operation, i.e. when
30 being driven, and also terms „antenna„ and „beam„ are
used interchangeable, as the antenna configuration and
driving will determine the produced beam. It is to be
noted further that when considering diversity, a
diversity branch can also be represented by the beam
35 produced by the corresponding (diversity) antenna array.

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To recapitulate, there are different transmit diversity
modes in FDD WCDMA (FDD = Frequency Division Duplex,
WCDMA = Wideband Code Divisional Multiple Access)
5   dedicated downlink channels:
      1) an open-loop diversity mode using space-time codes
         such as for example the concept known as STTD (Space-
         Time Transmit Diversity), and
      2) a closed-loop diversity mode, which can be classified
10   into different closed-loop diversity classes:
      a) a first class, subsequently referred to as Class 1, in
         which the receiver (e.g. a user equipment UE) returns
         information to the diversity transmitter (e.g. a
         Node_B) concerning the relative phase of the received
15   diversity transmission signals; an example for such a
         Class 1 closed-loop diversity mode is known as closed-
         loop mode 1; and
      b) a second class, subsequently referred to as Class 2,
         in which the receiver returns information to the
20   diversity transmitter concerning the relative phase and
         the ration of received powers of the received diversity
         transmission signals; an example for such a Class 2
         closed-loop diversity mode is known as closed-loop mode
         2 (as for example described in the above cited book by
25   Juha Korhonen or as described by 3GPP TS 25.214:
         "Physical Layer Procedures (FDD)").

It is to be noted that closed-loop diversity is only
applicable to a downlink channel if there is an
30 associated uplink channel which is required to return the
feedback information. An example for such a channel
combination is represented by the DPCH (Dedicated
Physical CHannel) / DPCCH (Dedicated Physical Control
CHannel) channels.

35

First, the present transmit diversity methods in WCDMA
are recalled. The present (standardized) Transmit
Diversity Methods in FDD WCDMA dedicated downlink
channels are, as mentioned herein before, for example

5   - STTD (Space-Time Transmit Diversity) as an open-loop
       solution utilizing a simple 2x2 space-time code,
     - closed-loop mode 1 (CL1) as an example for class 1
       closed-loop diversity according to which the relative
       phase between transmitted signals is adjusted based on

10   the feedback from the receiver (user equipment), and
     - in closed-loop mode 2 (CL2) as an example for class 2
       closed-loop diversity according to which both, relative
       phase and power between transmitted signals, are
       adjusted based on the feedback from the mobile.

15

The Node_B as the transmitter (corresponding in its
functionality to a base station BS known from GSM system)
can select the mode to be used for each link separately
or it can use the same mode for all links in the cell. In

20   this invention, however, the former case is studied,
since the latter solution is not recommended because it
does not utilize the available capacity potential.

Generally, the mode selection problem resides in finding

25   measures and a method by which a best suitable mode can
be selected for each link.   A „best suitable mode" can be
determined as the mode which reveals the best performance
(e.g. lowest bit error rate, lowest S/N (signal to noise)
ratio, or the like).

30

The mode selection problem is linked to the employed
antenna solution at the transmitter. The present transmit
diversity modes are designed by assuming that the average
received powers at the receiver side (UE) from separate

35   transmitter (Node_B) antennas are the same. Thus, if

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average power of signals received at the UE and
originating from an antenna Ant1 is denoted by P1 and
average power of signals received at the UE and
originating from antenna Ant2 is denoted by P2, so that

5   the ratio thereof, P1/P2 = 1. When this assumption holds,
the performance of the closed-loop schemes depends in a
certain manner on the feedback delay and on the spatial
correlation between transmit antennas. If the ratio P1/P2
is not equal to unity, then the sensitivity of closed-

10   loop modes to the feedback delay and spatial correlation
between transmit antennas will be different than in case
P1/P2 = 1. This can be illustrated by a simple example.
If transmitter selection combining is used, then the
signal is transmitted trough the antenna which provides

15   better channel. Feedback information from a mobile
directs the transmit antenna selection. If P1/P2 = 1 in
the receiver, then both received channels are in good
state with equal probability and system performance
depends on the feedback delay and transmit antenna

20   correlation. If feedback delay is large when compared to
channel coherence time, then system performance is
corrupted. Similarly, if transmit antennas correlate
heavily, then both antennas are in good and bad states
simultaneously and the lack of diversity corrupts the

25   system performance. However, if P1/P2 is all the time
very high - or very low - then the same antenna provides
better channel almost all the time and feedback delay or
antenna correlation are not corrupting the system
performance much. The effect of P1/P2 is not the same to

30   all transmit diversity modes and therefore it should be
taken into account when transmit diversity mode is
selected.

In Fig. 1 there is a sketch concerning to the selection
· 35   problem when average received powers from separate BS

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antennas in MS are equal: areas A, B and C (also referred
to as mapping areas) consist of those spatio-temporal
correlation value pairs (spatial correlation SC, temporal
correlation TC) for which open-loop mode (e.g. STTD),
5   class 1 closed-loop mode (e.g. CL1) and class 2 closed-
loop mode (e.g. CL2), respectively, provide the best
performance. Apparently, the open-loop mode (STTD) is the
best choice in most cases while the operating area of
Class 2 closed-mode is marginal: Class 2 is suitable only
10   when time correlation (TC) is very high. Class 1 works
well when spatial correlation (SC) is relatively high. It
is to be noted that the Figure 1 is only a sketch.

The assumption that average received powers at the
15   receiver would be equal is well posed, if
(a) Transmit antennas are co-polarized
(b) Transmit antenna separation is not very large (i.e.
antennas are in the same site, and not, for example, in
separate buildings).
20
The latter restriction (b) is not a problem in practice
since the diversity antennas are usually in the same
mast. However, assumption (a) has some drawbacks.

25   The well known fact is that two low correlated signals
can be obtained using cross-polarized antennas (and/or
antenna arrays). This antenna solution is more compact
and cheaper than a pair of spatially separated co-
polarized antennas / antenna arrays. Moreover, beside
30   these known advantages, the so-called polarization
mismatch can be avoided by using cross-polarized antenna
arrays / antennas. This is explained in the following.

Polarization Mismatch Problem:

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In a conventional system, a single vertically polarized
antenna is used at the transmitter side. This arrangement
is feasible if receiver antennas are all vertically
polarized. However, this will not be the case in
5   practice. It may even happen that receiver antenna
polarization is flat, a horizontally oriented ellipse, or
the like. Then huge polarization mismatch losses can be
faced.

10   Also, different physical environments preserve the
transmitted polarization in a different way and thus, the
danger of polarization mismatch depends on the
environment; in open areas the probability of a serious
mismatch is expected to be high.

15
The known solution to this problem is the use of cross-
polarized antenna arrays and/or antennas. In GSM related
solutions, the downlink (DL) signal is transmitted from
cross-polarized antenna branches with equal power   (each
20   individual diversity antenna corresponds to a
transmitting branch). The relative phase between the
signals transmitted from each branch is randomly rotated
in order to avoid the situation where signals would erase
each other for a long time (this may happen if antenna
25   brancnes have strong correlation, for example because of
a line-of-sight (LOS) situation). This solution prevents
the total mismatch between the transmitter and receiver
polarizations.

30   The same method as used in GSM is, however, not
straightforward to be used in WCDMA, since channel
estimation at the receiver UE is based on common pilot
channel (CPICH). However, if downlink transmit diversity
is used, then different CPICHs are transmitted from
35   separate antenna branches and cross-polarized antennas

can be employed. Stated in other words, each via each
antenna of the transmit diversity antennas a respective
CPICH is transmitted.

5   The present WCDMA standards specify in a detailed manner
the allowed transmit diversity modes and hence, if cross-
polarized antennas are used in connection with transmit
diversity, then the special properties of this antenna
solution must be taken into account in the limits given
10   by standards.

Summarizing, it has to be noted that
(a) if co-polarized, spatially separated antennas are
used in connection with WCDMA transmit diversity modes,
15   then mode selection can be based on a fixed performance
chart such as the one proposed in Figure 1;
(b) based on compact structure, costs and robustness
against polarization mismatch, the use of cross-polarized
diversity antennas is a very attractive solution.
20   However, when used, this renders the usage of a fixed
performance chart such as the one proposed in Figure 1
not feasible, as will subsequently be explained.

Special Characteristics of Cross-Polarized Antenna
25   Arrays:

Currently, the present transmit diversity modes are
studied based on the assumption that the average received
powers at the receiver originating from separate
30   transmitter antennas are equal (P1/P2 = 1). This is,
however, not necessarily true for cross-polarized antenna
arrays if the XPR (cross-polarization ratio) in the
channel is high. This is the case especially in rural
environments where orthogonal polarization branches are
35   not mixed well and it has been claimed that XPR is

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relatively high even in urban outdoor environments (See
for example Shapira J. and Miller S. in „A novel
polarization smart antenna„, VTC, May 2001, or in
„Transmission Considerations for polarization-smart
5   antennas„, VTC, May 2001. See also „Method and System For
Improving Communication„ by Shapira J. and Miller S.,
International Patent Application WO 98/39856).

Thus, although there might be low correlation between BS
10 antenna branches, the average received power at the
receiver from cross-polarized BS antenna branches can be
different (P1 ≠ P2); this renders the usage of a fixed
performance chart such as the one proposed in Figure 1
not feasible, or at least its usage will result in a non-
15 optimum diversity mode selection.

Summary of the invention

Consequently, it is an object of the present invention to
20 provide an improved method for selecting a diversity mode
to be applied by a transmitter having two cross-polarized
antenna arrays, each representing a diversity branch,
for transmission diversity, which is free from the above
mentioned drawback.
25
According to the present invention, the above object is
for example achieved by a method for selecting a
diversity mode to be applied by a transmitter having two
cross-polarized antenna arrays, each representing a
30 diversity branch, for transmission diversity, the method
comprising the steps of: providing a plurality of
diversity mode performance chart look-up tables, each
performance chart look-up table mapping a respective
individual diversity mode out of a plurality of
35 individual diversity modes to a respective pair of time

correlation value and space correlation value for said
two cross-polarized antenna array beams, wherein a
respective individual diversity mode is presented by a
mapping area, wherein the plurality of performance chart
5   look-up tables is parameterized by an indication of a
ratio of received powers from said diversity branches,
and the mapping is different for different performance
charts, first determining the ratio of received powers
from said diversity branches, second determining the
10   actual time correlation and space correlation for said
pair of two cross-polarized antenna arrays, first
selecting one of said performance chart look-up tables
dependent on determined ratio of received powers from
separate beams, and second selecting one of said
15   individual diversity modes according to the mapping to
the determined actual time correlation and space
correlation values from said first selected performance
chart look-up table.

20   According to favorable further developments
       - said selected diversity mode is selected for each
individual link established by the transmitter;
       - said mapping of diversity modes differs for
different performance chart look-up tables dependent on
25   the determined ratio of received powers from said
diversity branches;
       - said diversity modes are classified as open-loop
diversity modes and closed-loop diversity modes, and said
determined ratio of received powers is applied as a
30   further control parameter for controlling said closed-
loop diversity modes when activated upon selection;
       - said diversity modes are classified as open-loop
diversity modes and closed-loop diversity modes, and a
mapping area of at least one closed-loop diversity mode

increases dependent on the indication of a ratio of received powers from said diversity branches;

    - said first determining and said second determining are performed at said transmitter;

    - providing said performance chart look-up tables is effected beforehand based on simulation results and/or measurement cycles; and

    - both arrays consists of one antenna element and antenna calibration in the transmitter is performed by using both the feedback from said receiver according to one of the closed-loop modes, and the received signals from cross-polarized antenna arrays in the transmitter.

By virtue of the present invention, basically the following advantages can be achieved

    - The present invention provides a new solution for diversity mode selection to be used in two-antenna array transmit diversity systems, in particular those using cross polarized antenna arrays.

    - The present invention provides means to combine polarization matching and present WCDMA transmit diversity modes.

    - The mode selection procedure depends on the difference between average received powers, so that the appropriate look-up table may be selected resulting in improved diversity performance,

    - The present modes (in limits given by standards) can be enhanced as they take into account the difference between average received powers.

Thus, this invention improves the present solutions in two ways in that firstly, it provides means to combine polarization matching with present transmit diversity modes, and secondly, it provides a new transmit diversity selection procedure that is based on BS measurements.

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Brief description of the drawings

In the following, the present invention will be described
5   in greater detail with reference to the accompanying
drawings, in which

Fig. 1 shows a diversity mode performance chart look-up
table mapping a respective individual diversity mode out
10 of a plurality of individual diversity modes to a
respective pair of time correlation value and space
correlation value, under the assumption that the ratio of
received powers equals 1;

15 Fig. 2 shows a diversity mode performance chart look-up
table mapping a respective individual diversity mode out
of a plurality of individual diversity modes to a
respective pair of time correlation value and space
correlation value, under the condition that the ratio of
20 received powers is unequal to 1, and rather is in the
range of for example 3 to 6 dB;

Fig. 3 shows a diversity mode performance chart look-up
table mapping a respective individual diversity mode out
25 of a plurality of individual diversity modes to a
respective pair of time correlation value and space
correlation value, under the condition that the ratio of
received powers is unequal to 1, and rather is in the
range of for example greater than 6 dB;

30
Fig. 4 is a simplified block diagram of a transmitter
with the present invention being implemented; and

Fig. 5 is a flowchart illustrating the method according
35 to the present invention.

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Detailed description of the embodiments

In the following, the proposed mode selection procedure
5   according to the present invention is outlined. It is to
be noted that in the below procedure all steps are
performed in the transmitter (e.g. BS). The procedure as
such basically comprises the following steps when
selecting a diversity mode A, B, C to be applied by a
10 transmitter having two cross-polarized antenna arrays
Ant1, Ant 2, each representing a diversity branch, for
transmission diversity.

Firstly, a plurality of diversity mode performance chart
15 look-up tables LUT, LUT1, LUT2, LUT3 are provided, step
S10. Each performance chart look-up table maps a
respective individual diversity mode A, B, C out of a
plurality of individual diversity modes to a respective
pair of time correlation value TC and space correlation
20 value SC for said two cross-polarized antennas, and a
respective individual diversity mode is presented by a
mapping area (in the chart). The plurality of performance
chart look-up tables is parameterized by an indication of
a ratio P1/P2 of received powers (at the receiver side)
25 from said diversity branches, and the mapping is
different for different performance charts. The look-up
tables have been formed beforehand, i.e. before the
actual selection process starts.

30 Subsequently, there is a first determining step, S11, for
determining the ratio of received powers from said
diversity branches. This determination can be effected by
computing the ratio between average received powers from
separate antenna branches. Namely, the receiver UE
35 transmits in uplink direction UL feedback information FBI

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indicating the relative phase of the signals transmitted
/ received from the antenna branches, and from this
information, the transmitter can in turn deduce the
relative strength, i.e. received power. The average
received power is obtained by averaging the information
on the relative strength/power received from a plurality
of receivers (mobile station and/or user equipment), as
each FBI concerns a certain receiver only.

Next, in a second determining step S12, the actual time
correlation TC and space correlation SC for said pair of
cross-polarized antennas is performed. This can be
accomplished by computing the channel time correlation
employing the data from both receiver antenna branches by
using any known method, and likewise, also by computing
the spatial correlation between antennas by using
received data and any known method. The computation of
the time correlation of signals can be done, for example,
in the transmitter based on the equation

$$TC(d) = \frac{E\{x(t)^* x(t-d)\}}{\sqrt{E\{|x(t)|^2\}E\{|x(t-d)|^2\}}}$$

where x(t) is the received signal in the transmitter at
time instant t, x(t-d) is the received signal in the
transmitter at time instant t-d and E{.} is the
expectation. Expectations can be estimated using IIR or
FIR filters. The symbol „*„ denotes the conjugate complex
value. The correlation between antenna branches can be
done based on the equation

$$SC = \frac{E\{x1(t)^* x2(t)\}}{\sqrt{E\{|x1(t)|^2\}E\{|x2(t)|^2\}}}$$

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where x1(t) is the received signal in the transmitter
antenna 1 at time instant t, x2(t) is the received signal
5   in the transmitter antenna 2 at time instant t and E{.}
is the expectation. Again, suitable IIR or FIR filters
can be used in order to estimate the expectations, and
the symbol „*„ denotes the conjugate complex value..

10   Based on those spatio-temporal correlation values and
power ratio determined as described above, a decision can
then be taken on the most suitable diversity mode to be
used and/or activated for diversity transmission, the
decision using the look-up table LUT consisting of plural
15   individual look-up tables LUT1, LUT2, LUT3 that have been
formed beforehand.

Namely, there is performed a first selecting step S13 of
one of said performance chart look-up tables dependent on
20   determined ratio P1/P2 of received powers, i.e. for
example LUT2 is selected because the ratio P1/P2 is in
the range of 3...6 dB for which LUT2 is applicable, and
thereafter a second selecting step S14 of one of said
individual diversity modes A, B, C according to the
25   mapping to the determined actual time correlation TC and
space correlation SC values from said first selected
performance chart look-up table is performed. Stated in
other words, considering that LUT2 resembles the
performance chart shown in Fig. 2, assuming that (TC;SC)
30   has a value of about (0,9;0,9), for example, then the
value pair lies within the mapping area denoted by arrow
C and the closed-loop diversity mode of class 2 would be
selected.

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Thus, the principle of mode selection has become clear
from the above explanations of the provisioning,
determination and selection steps. Known algorithms can
be used in the determination steps while the provisioned
5   look-up table can be established based on simulations
and/or the transmitter tests.

Fig. 5 represents the above explained method steps as a
corresponding flowchart diagram.
10

Accordingly, the mode selection procedure according to
the present invention can be based, as derivable from
Figs. 1, 2 and 3, on three measures and/or parameters
that can be used in mode selection, namely: time-
15   correlation TC between signals from separate antennas,
spatial correlation SC between separate antennas and the
ratio between average received signal powers P1/P2. There
are, of course other measures too, but the inventors
emphasize the given measures since
20   - they are essential from a performance point of view,
- they can be computed in BS and
- most (or even all) other important measures (MS
velocity etc.) can be derived from the given
measurement set.
25

According to a modification, the closed-loop diversity
mode of class 2 can be enhanced. Namely, as mentioned
before, said diversity modes are classified as open-loop
diversity modes A, and closed-loop diversity modes B, C,
30   and said determined ratio of received powers P1/P2,
according to the modification, is applied as a further
control parameter for controlling said closed-loop
diversity modes when activated upon selection.

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This will subsequently be explained in greater detail. In
the present Class 2 closed-loop modes, the receiver (MS
or UE) estimates the channels from two different CPICHs
and selects the best transmit weight combination from a
5   standardized quantization set. Then receiver transmits
the feedback information (4 bits) to the BS via a control
channel (e.g. DPCCH). In the transmitter such as the BS
or Node_B, the suitable weights are selected and/or
generated based on the feedback. Finally, the receiver MS
10 may use a certain verification algorithm by which it
confirms that the transmitter BS has used correct weights
(see for example R1-00-1087, verification algorithm for
closed-loop transmit diversity mode 2, TSG RAN WG1, Aug,
2000). If there are feedback bit errors, then weights
15 used by the transmitter BS are not those that were asked
by the receiver MS, but verification algorithm will find
this out and correspondingly change its weights (in
channel estimation based on the common pilots, i.e.
CPICH's).
20

If, however, cross-polarized antenna arrays (and/or
antennas) are used, then the following enhancement can be
used.

25 1. The receiver estimates the channel, forms the feedback
and transmits it to the transmitter as in the present
closed-loop mode of class 2.
2. The transmitter uses the standardized quantization in
weight selection. However, it does not use the receiver
30 feedback directly, but instead, it employs both the
feedback received from the receiver as well as uplink
measurements in connection with weight selection.
3. MS verifies the weights that are used by BS.
4. BS verifies that employed weights are suitable.

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Various possibilities in regard of detailed algorithm
proposals for such an enhanced control can be presented,
which may vary dependent on measurement campaign results
conducted for specific environments and transmitters.
5   However, basically it should be noted that the received
power and/or average received power is to be used as an
additional control parameter for weight selection in
diversity transmission.

10   According to a basic implementation of the enhanced
modification, the transmitter BS/Node_B computes the
average received powers P1 and P2 of some certain link
from separate antenna branches and uses the ratio P1/P2
in weight selection. The weight computation can also be
15   based on the relative phase information received via the
FBI bits from a certain receiver. The received FBI
information concerning to a certain radio link can be
either used directly or it can be filtered before it is
used.
20

According to an alternative implementation of this
aspect, in many environments the amplitude (and in some
cases even phase) weight selection can be based on uplink
measurements when cross-polarized antennas are used. For
25   example, received signal powers from separate antennas
can be filtered as follows,

$$P1(t)=aP10+(1-a)P1(t-1)$$
$$P2(t)=aP20+(1-a)P2(t-1)$$

30

where P1(t) is the filtered power from antenna 1 at time
t, P10 is the instant power from antenna 1, P1(t-1) is
the filtered power from antenna 1 at time t-1, P2(t) is
the filtered power from antenna 2 at time t, P20 is the
35   instant power from antenna 2, P2(t-1) is the filtered

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power from antenna 2 at time t-1 and a is a filtering
parameter. When the channel preserves the transmitted
polarization, it can be seen from uplink measurements
when observing the ration p1/p2: If the ratio p1/p2 is
5   not equal to unity, then channel preserves the
transmitted polarization at least partly and it can be
utilized when downlink transmit weights are selected. In
some cases the channel preserves also the relative phase
between transmitted (and received) signals.
10

The transmitter verification can be based on the averaged
FPC (Fast Power Control) bits that are received from the
receiver. Thus, the proposed enhanced class 2 closed-loop
diversity mode does not need any standard changes.
15   The performance can be further improved by extending the
definition of the field of applicability of the class 2
closed-loop diversity mode in the standard. Namely, the
standard commands to send 80% of the power from the
better channel and 20% of the power from the other one.
20   However, if the power imbalance is large, it is better to
transmit from one antenna only. Stated in other words,
depending on a threshold of power imbalance, diversity is
then switched off. Optional transmit weight verification
in the receiver side should still be viable if the
25   changes in power allocation based on uplink measurements
are smooth enough.

Next the benefit obtained by the proposed enhancement is
illustrated. Assume that cross-polarized antenna arrays
30   are used and ratio p1/p2 of received powers from separate
polarization branches is relatively large (currently,
there are no simulation results yet available and
therefore Figure 2 is based on theoretical
considerations). It is assumed that here 'relatively
35   large' means 3-6dB's). Then the performance chart has the

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form given in Figure 2 (now C refer to enhanced class 2).
It is seen that the operating area of enhanced class 2
has been increased. This is mainly because enhanced class
2 begins to work better when ratio p1/p2 increases.

5   Moreover, there are not as many wrong decisions
corresponding to amplitude weights when enhanced class 2
is used. This is especially true when spatial correlation
is high. In Figure 3 there is illustrated the performance
chart when the ratio of received powers from separate

10   polarization branches is large (> 6dB's). It is seen that
enhanced class 2 begins to dominate when power ratio
increases. In fact, when ratio p1/p2 is (very) large (6dB
corresponds to a ratio of P1/P2 = 4/1), then enhanced
class 2 may be the most feasible mode for all spatio-

15   temporal correlation values. This is, however, an extreme
case.

When enhanced class 2 is used, transmit weight selection
may be based on both receiver feedback and uplink

20   measurements. This means that antennas need to be
calibrated. For calibration, a method as explained
further below can be used.

However, there is also an other way that may be faster

25   and more accurate, which is described in the following.
We emphasize that the subsequently proposed calibration
procedure neither need any additional hardware in BS, nor
any standard changes.

30   Basically, every antenna array is provided with an
equipment for modifying the baseband signal so that the
signal leaving the antenna array to the physical layer,,
i.e. the air interface in radio transmission systems, is
known. When there are two transmit antennas and also two

35   transmit chains, this means that two basebands, two D/A

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converter, two power amplifiers etc. are provided, thus
establishing two RF chains, one chain per antenna.

5   However, even though each chain is similar in design, the
    used components are actually slightly different because
    of their non-ideal characteristics. Hence, also the
    signal leaving the antenna system is not the same per
    antenna, even if controlled by the identical control
    signals. As a consequence, signal phase between the
10 signals of the chains is not preserved in the RF chains.
    Accordingly, a phase compensation by means of applying a
    transmit weight at the baseband side has to be effected
    for compensating the phase error. Determination of the
    weight to be applied represents the calibration problem.

15

    To this end, just before the antenna, a receiver means
    (still at the transmitter) is provided, which measures
    the transmitter's own signal. Based on this, the non-
    idealities are determined and the weight for compensation
20 is deduced.

    - For the proposed calibration, such receivers are
    selected for which the channel preserves well the
    polarization. This will make the calibration more
25 reliable. If there are none, then the enhanced class 2 is
    not used (it is not feasible) and calibration is not
    necessarily needed. (Preservation of polarization can be
    recognized from the received power ratio p1/p2.)
    - By averaging received signal powers and relative phases
30 between polarization branches, suitable transmit weights
    for downlink transmission are found (for each link
    separately). But these weights are not used immediately.
    - Then, comparison is effected of (a) the transmit
    weights that are formed using received feedback commands
35 and (b) transmit weights that are formed using

polarization measurements. The possible difference in the
transmit weights is the error that needs to be
compensated by calibration. Since several receivers (at
least one) is connected into the calibration process, the
resulting calibration constants (same for all mobiles)
are obtained using the average differences in transmit
weights. This calibration procedure is fast and no
additional hardware is needed. If closed loop diversity
mode class 1 is employed, then the relative phase between
transmit chains can be calibrated as explained. Relative
transmit power can be calibrated when class 2 is
employed, at least for some links.

For example, if closed-loop mode class 1 is employed, we
can do the calibration as follows: assume that K
receivers are connected to the calibration. Receivers are
selected such that correlation between antennas is high.
This is, for example, the case if there is strong line-
of-sight (LOS) component in the received signal. For the
relative phases there holds

$$(1) \quad \boxed{\begin{aligned} \Delta\phi^k_{UL,ANT} &= \Delta\phi^k_{UL,DSP} + C_{UL} \\ \Delta\phi^k_{DL,ANT} &= \Delta\phi^k_{DL,DSP} + C_{DL} \end{aligned}}$$

Where left side of the equation is the relative phase
between signals when signals leave the antennas, first
term in the right side of the equation is the relative
phase of signals seen in digital signal processing (DSP)
unit before transmission and the last term in the right
is the calibration constant. First equation corresponds
to the receiver chains while second equation corresponds
to the transmitter chains. Index k refers to the
receiver. If antennas are correlated we should have

(2) $$\Delta\phi^k_{UL,ANT} = \Delta\phi^k_{DL,ANT}$$

Then transmitted signals are summed coherently in the direction of the receiver k. If closed-loop mode class 1 is used this equation is approximately true. Then we obtain

(3) $$\Delta\phi^k_{UL,DSP} - \Delta\phi^k_{DL,DSP} = \Delta\phi^k_{UL,ANT} - \Delta\phi^k_{DL,ANT} + C_{DL} - C_{UL}$$

Now the difference between calibration constants is estimated using equation

(4) $$C_{UL} - C_{DL} \approx \frac{1}{K}\sum_{k=1}^{K}\left(\Delta\phi^k_{DL,DSP} - \Delta\phi^k_{UL,DSP}\right)$$

After estimating the difference between calibration constants we can select the relative phase for transmission using the equation

(5) $$\Delta\phi^k_{DL,DSP} = \Delta\phi^k_{UL,DSP} + C_{UL} - C_{DL}$$

Hence, only UL measurements are needed any more. Calibration needs to be updated once and a while. Update time is system related.

Fig. 4 shows a transmitter implementing the present invention, i.e. the method for diversity mode selection, the method for controlling the mode to an enhanced mode, and the calibration method. However, please note that details of implementation are omitted and that Fig. 4 shows merely a basic functional block diagram, while even

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omitting details concerning the calibration process in
order to keep the description simple.

As shown in Fig. 4, the transmitter comprises a look-up
5   table LUT, which itself consists of a plurality of look-
up table performance charts LUT1, LUT2, LUT3. For
example, LUT3 and LUT2 may have a contents as represented
in Figs. 3 and 2, respectively, while LUT1 may have a
contents basically as represented in Fig. 1. (Note that
10   Fig. 1 illustrates a case for P1=P2, while LUT1 in Fig. 4
is intended to be used for a range of P1/P2= 0...3 dB).
Further look-up table performance charts may be used
and/or the power ration ranges may vary from those
indicated in Fig. 4. Furthermore, the transmitter
15   comprises two diversity antennas Ant1 and Ant2, each
preceded by an RF chain RF1, and RF2, respectively.

The RF chains are controlled by applying at least a
weight signal, output from a weight selection means. The
20   weight selection means is at least controlled by a
control signal output from a control means CTRL. The
output of the control means CTRL is dependent on feedback
information received from a receiver (not shown).
(Basically, this weight control arrangement as described
25   so far corresponds to prior art).

The control means receives the feedback information and
determines a control signal for weight selection. In
addition, the control means also determines the ratio of
30   received powers P1/P2 and the space correlation SC and
time correlation TC values. This determination can be
based on the received feedback information and determined
by calculation, or may be based on uplink measurements.

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The determined ratio P1/P2 is applied for controlling the
selection of one of the look-up table performance charts
LUT1 to LUT3 dependent on P1/P2. (This is indicated by
the controlled switch controlled by P1/P2.) Once a look-
5   up table performance chart is selected, the parameters TC
and SC are applied to select the appropriate diversity
mode therefrom, indicated in the performance chart for
this parameter pair. The thus selected diversity mode is
then activated by applying a diversity mode control
10   signal DMC to the RF chains. (Note that the selection
order can also be exchanged, i.e. first TC/SC selects in
each of LUT1 to LUT3 a mode to be selected, and one of
the thus pre-selected modes is then selected based on
P1/P2.) Additionally, the power ratio P1/P2 may also be
15   applied for weight selection, as shown in Fig. 4.

Accordingly, as has been described herein before, the
present invention concerns a method for selecting a
diversity mode A, B, C to be applied by a transmitter
20   having two cross-polarized antenna arrays Ant1, Ant 2,
each representing a diversity branch, for transmission
diversity, the method comprising the steps of: providing
S10 a plurality of diversity mode performance chart look-
up tables LUT, LUT1, LUT2, LUT3, each performance chart
25   look-up table mapping a respective individual diversity
mode A, B, C out of a plurality of individual diversity
modes to a respective pair of time correlation value TC
and space correlation value SC for said two cross-
polarized antenna array beams, wherein a respective
30   individual diversity mode is presented by a mapping area,
wherein the plurality of performance chart look-up tables
is parameterized by an indication of a ratio P1/P2 of
received powers from said diversity branches, and the
mapping is different for different performance charts,
35   first determining S11 the ratio of received powers from

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said diversity branches, second determining S12 the
actual time correlation and space correlation for said
pair of two cross-polarized antenna arrays, first
selecting S13 one of said performance chart look-up
5   tables dependent on determined ratio P1/P2 of received
powers from separate beams, and second selecting S14 one
of said individual diversity modes A, B, C according to
the mapping to the determined actual time correlation TC
and space correlation SC values from said first selected
10 performance chart look-up table.

While the invention has been described with reference to
a preferred embodiment, the description is illustrative
of the invention and is not to be construed as limiting
15 the invention. Various modifications and applications may
occur to those skilled in the art without departing from
the true spirit and scope of the invention as defined by
the appended claims.